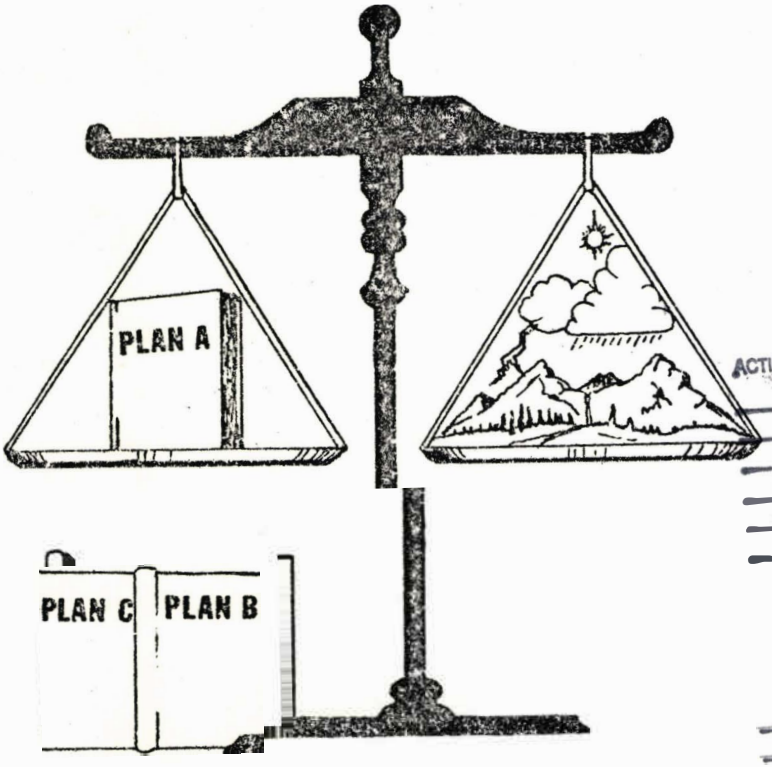
FOCUS

(Fire Operational Characteristics Using Simulation)

STATUS REPORT



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September 1977

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FOCUS OPERATIONAL RELIABILITY

I. FOCUS VALIDITY

A. System Validity

1. User Experience

a. Western Application

For the past two years FOCUS has been tested over a wide range of conditions throughout National Forests in the western United States. In addition, it has been evaluated by the Bureau of Land Management and the California Department of Forestry. The FOCUS System handles most of the problems associated with western fire control; most of the western firefighting techniques, strategies, and procedures have been modeled satisfactorily. Users who have done intensive analysis are usually pleased with the model's performance. FOCUS has enough flexibility and capability to cope with a very wide range of situations. Where FOCUS does not explicitly have the capability of modeling a situation, users have applied their ingenuity in finding ways of adapting the model to the particular sitution. A typical example is adapting the smokejumper technique to helicopter rappelling. While FOCUS's flexibility allows it to be adapted to a wide range of problems, it has also added to its complexity--FOCUS is not easy to use.

A number of major decisions have been made using FOCUS as a guide. These include emergency appropriations for the California Department of Forestry due to drought conditions in California and equipment assignment to prevention patrolmen on the Sequoia National Forest. Region 6 National Forests have used FOCUS output for budget justifications. At this time, we believe the model adequately meets the needs of most western fire planners.

b. Northeastern and Southeastern Applications

The model is currently undergoing tests in several National Forests in the eastern part of the United States and tests are planned in the states of Wisconsin, Maine, and Georgia. The current operating model has several shortcomings that are being corrected. These include the inability to simulate indirect head attack by tractor plows (with backfiring), refill capability for fire trucks or air tankers, and dual use of aircraft for crew transport and then as air tankers. The firetruck refill mode will allow trucks to refill from local water sources and return to the fire prior to return to the station. (This is in contrast to the technique used in the west where tanker crews more generally become hand crews when their truck's water is exhausted, or refill from nurse tankers.)

c. General

In general, planners who have used FOCUS and are familiar with it (with some exceptions to be discussed under sensitivity) seem to be most satisfied with its operational use. This is primarily because the skills in obtaining and handling large quantities of data involved and familiarity with the potential use options that FOCUS offers must be learned. Users have found that FOCUS offers the flexibility to meet almost all fire planning situations they run into, but on the other hand requires a great deal of skill, capability, and knowledge of both computer technology and basic fire fundamentals to make adequate use of it.

2. Verification of Data and Run Set-ups

a. Prechecking

Users have found that their accuracy and efficiency in using FOCUS is greatly improved by making a series of prerun checks and tests. A number of facilitating computer programs have been written

to aid in this process. They check the transportation network or fire locations for accuracy and include a routine for checking the connection of road segments and the travel times over the segments for various types of vehicles. The user can check the reasonableness of travel time between intersections. A second routine plots a map of the road system and fire locations. The map can actually be overlaid on the unit's operational map to determine if the road and intersections are in their proper locations. Users have found through experience that these are necessary first steps.

b. Validity Checking and "Fine Tuning"

Chapter 7, of the new User Manual, gives a detailed procedure for what we believe is an essential second step. After a small set of fires have been run on the FOCUS system (perhaps 100 or so) a team of two or three individuals thoroughly familiar with the agency's fire problems should examine each fire on a case by case basis. The users look at the resource mix, arrival times and eventual size for each of the fires to determine if they are reasonable. Illogical helitack, smokejumper, or crew performance, unreasonable use of cooperators, etc., may be the result of 3 kinds of problems. The first and most likely case is a coding error in which data was entered into the system incorrectly.

A second problem involves mistakes in operational alternatives covering such procedures as dispatch action, dispatch lag time, manning patterns, manning guides, use of secondary resources, and various operational rules. Frequently, a FOCUS "anomaly" results in some real soul searching as to "how do we really do it in the field?" The FOCUS User Manual gives step-by-step validity checking procedures and analysis techniques. A great majority of these runs or data parameter problems are quickly found by users familiar with both the FOCUS system and the firefighting methodology of the agency.

The third problem, "program glitches" is becoming less important with time as errors are detected and weeded out. Large computer programs are probably never completely error free. We envision that from time to time users will run into a situation that has not been tested heretofore and find an unexpected program bug still remaining.

The User Manual gives step-by-step validity checking pro cedures and analysis techniques. A great majority of these are quickly found by users familiar with both the FOCUS system and the firefighting methodology of the agency.

c. Diagnostics

Although not normally used in conventional FOCUS output, the program has been written so that a wide range of diagnostic output can be obtained. These include a step by step tracing of the movements of various firefighting resources through the transportation network and through the air. Detailed line building and holding activities of each unit of the fire suppression forces can be analyzed. If there is a question about how a unit traveled to, or performed on a given fire it is possible to analyze it in any degree of depth desired.

3. Analytical Tests

a. Fire Size Class Comparison

The fire size class distribution from FOCUS runs using Base Plan information have been compared to what had actually occurred during the past 5 years on several test forests. In all comparisons, the FOCUS size class distribution was very nearly identical to what had actually taken place.

b. Statistical Tests

Chi-Square Tests

Chi-Square tests were run on a fire by fire basis with FOCUS simulation and Base Plan operation for the Sequoia National Forest for 1960 and 1967 (the fourth worst years for that decade). (See Appendix A.)

B. System Sensitivity

1. Sensitivity to Data Precision

The FOCUS staff is currently conducting sensitivity analyses with the various input variables used by FOCUS. We expect these tests to be completed this fall. The objective is to analyze input data requirements and develop recommendations to make data preparation more efficient; and to identify data variables which appear most reliable.

2. Sensitivity to Alternate Plans

Another question regarding type of sensitivity is, how FOCUS responds to changes, both small and large, within fire plans. We want responses that would be expected in the real world if the plan changes simulated were actually put into effect. Wild fluctuations in FOCUS output related to a small plan change would not be realistic, for example.

In general, fire planners base their organization on some concept of the "average worst" situation. In the U.S. Forest Service 1972 fire plan, it was based on the 90th percentile (worst) weather situation. In other words, we might expect the Forest Service suppression organizations (and we assume many State and Federal land management organizations as well) to be somewhat over-strength most of the time. On the other hand, under extreme conditions of weather,

fuel, and slope, we are going to lose a few fires no matter how strong our organization is. We have all seen this when spot fires get away under extreme conditions while we have an organized force already at the scene. Most Forest Service fire suppression organizations probably are under-strength from 2 to 10 percent of the time depending upon the local fire problem.

Consequently, it is only a small percentage of the fires--either because of burning conditions or multiple fire situations--where the precise organizational strength matches the fire problem and fire containment is a "touch and go" operation. These are the fires that may or may not get away depending upon organizational capability and fire behavior. In other words, we have an organization that probably has overkill capability 75 to 80 percent of the time, but is seriously under-strength during extreme periods, perhaps 5 to 10 percent of the time, and balanced against the fire workload from 5 to 20 percent of the time. Minor, or even substantial, changes in organization strength aren't going to make much difference with the extreme or easy fires either in the real world or on FOCUS simulation runs. This is particularly true for the easy fires on protection areas in which fire spread is something less than 1 chain per hour. It holds even more if the same manning plan is used for all fire danger rating levels, the fire organization is relatively powerful and there is strong shared support from adjacent fire protection units and cooperators, or if other facilities such as logging company crews are available. We have seen a number of cases where the FOCUS suppression module effectively substituted one kind of force that was reasonably available for another and if the fire situation was not serious there was no important consequence.

It should be borne in mind that even a major change in the staffing of one or two fire stations may be relatively insignificant when we compare it to the regular forces available to the protection

agency and even more so when we compare it to the total forces available including adjacent cooperators and other nearby units of the same agency. Since the organization is geared to average bad conditions, we would expect such a reduction to be critical on only a very small number of fires and we should not expect to see a dramatic change in the number of fires by various size classes over the fire season.

On the other hand, the user should not overlook the importance of the impact of the escaped and no dispatch fires (all forces tied up elsewhere). It is important to remember that throughout the west and perhaps much of the country, 95 percent of the damage and cost of fire suppression is done on the 5 or so percent of fires that "get away." While perhaps small compared to the total number of fires that might occur during a fire season, 3 or 4 additional escaped fires under some planning alternatives might make a very significant difference if they were gamed, costed and damage calculated.

In summary, sensitivity tests and user experience including some of the statistical tests mentioned above show that the FOCUS system is sufficiently reliable to be used for fire planning on National Forests and other Federal and State protected units throughout the western United States. Validation for eastern fire protection areas presently is incomplete but we have no reason to believe that it would be any different than the western conditions.

C. When FOCUS Should or Should Not Be Used

1. Fire Workload

It is difficult to give a rule of thumb about when a fire agency has an adequate workload to justify the use of FOCUS. A very heavy workload planning unit like the Angeles National Forest in

California, certainly needs FOCUS but it also presents a formidable data collection job with thousands of fires, hundreds of miles of roads, dozens of cooperating agencies, and a vast array of fire-fighting resources that must be somehow converted to computer usable data. Use of FOCUS by the Angeles would save perhaps hundreds of thousands of dollars, although the job will be time consuming and expensive. A small forest, on the other hand, with a limited fire load and a few roads might not need FOCUS as badly from a decision-making standpoint, yet the job would be quick and less expensive to do. Thus, geographical size is not necessarily a criterion--one of the quickest and easiest jobs for us to do was a large Bureau of Land Management district in Alaska that had almost no roads whatsoever and all transportation was done by air. This eliminated FOCUS' biggest job--transportation network analysis.

a. Magnitude of Planning Problem

FOCUS should generally be used when there is a difficult or intractable fire suppression planning problem that cannot be readily solved any other way. If management feels that there is no real fire problem or that they could adequately solve any problem that does arise, there is probably no need to use FOCUS.

b. Expertise on Staff

FOCUS is an exceedingly complex system and requires ready availability of both fire control and computer expertise. While these may not necessarily have to be available on the planning unit they must be available to that unit. There must also be a willingness to innovate and try new ideas.

c. Currency of Data

FOCUS operates on the past history of fire occurrence. We have estimated that it requires a set of about 400-500 fires for statistically valid results. However, for results to be reliable the set

of 400-500 fires should be obtained from a period of not more than 10 years. Otherwise, trends in fuel, weather, and use may have modified fire occurrence patterns to make them unrealistic.

d. Values at Risk

The resources involved must be of sufficient value that some benefit will accrue changing from a less to a more efficient fire plan--an ingredient in sensitivity. If values are very low, the least expensive plan is probably the best and usually this can be determined without FOCUS.

2. Size of Planning Unit

FOCUS is generally implemented on a planning unit basis. In the case of the Forest Service, this is usually a National Forest. FOCUS has been used on areas varying in size from 250,000 acres up to about 5 million acres. An upper limit to the size is probably related to the complexity of the problem. Often the limiting factor is the size of the transportation network. As the size of the area increases the road or transportation system may get so large and cumbersome that the data needs become excessive. It also becomes considerably more expensive to run the computer program since travel through all portions of the road system must be analyzed; running up the cost considerably. On the other hand, air travel or the use of air tankers, for example, could be analyzed over a very large geographical area at minimum cost.

3. When is FOCUS Cost Effective?

a. General Cost of Planning

A number of civilian government agencies have used as a rule of thumb that they should devote something like 2-1/2 to 3 percent of their budget for planning purposes. Agencies like the military who

the system there is something for almost everyone ranging from a 2-page leaflet for top executives to a Forms Manual for field data collection. In all, there are 8 parts to the total system. Its present status is:

COMPONENT	PUBLISHER	STATUS
Development of documentation	System Development Corporation	Completed
Fire-Computer Specialist User Manual	System Development Corporation	Completed. Copies distributed to operational test units

250 copies have been printed by the Government Printing Office and San Bernardino NF and will be distributed by about 10/1/77.

Develop and write documentation control system	Forrest Warthman & Associates	Completed
Develop & prepare Forms Manual	Forrest Warthman & Associates	Completed
Develop & produce executive brochure	PSW Forest & Range Exp. Stn.	Completed and distributed
Fire Managers Guide	Forrest Warthman & Associates	Completed. Copies distributed to all operational test units
FOCUS System Program Descriptions	Fred Bratten and W.O. Programmer	In process. Complete during FY 78
Develop and test trainers handbook	Training Working Team National Wildfire Coordinating Group	On National agenda-- Estimated completion FY 1980

III. PROGRAM MODIFICATIONS

At the November 1976 FOCUS Steering Committee meeting, the FOCUS Research Project agreed to undertake several suppression module program changes and additions. The need for these modifications had been expressed primarily by the eastern regions and states, but the other agencies represented at the Steering Committee meeting also expressed interest in having these changes made. While it is expected that the computer programming for these changes will be completed by about September 1, 1977, the complete process of making the new program available to all users including documentation will not be finished until October 1, 1977. A status report on the individual changes is as follows:

A. Head Attack Using Backfiring

The programming of this capability has been completed as of September 1, 1977. Plans are to make this feature available to users on about October 1, 1977.

B. Local Water Refilling for Ground and Airtankers

The programming and data schemes have been designed for these capabilities has been completed along with preliminary testing. These features will be available to users about October 1, 1977.

C. Improved Airtanker Capability

The programming for this feature was completed in the summer of 1976 using funding from Bureau of Land Management. Limited pilot testing was done using BLM data. Incorporation of these changes into the present suppression module and more testing still remains. The target is October 1, 1977.

D. Offroad Travel Barriers

This item, as in C above, was sponsored by the Bureau of Land Management and used in running one of their units on a pilot test. This feature will be included in a suppression module version which will be released about October 1, 1977.

E. Dual Use of Aircraft

An additional program feature which will be available about October 1, 1977 is the dual use of helicopters (or equivalent aircraft) to transport crewmen to a fire, then start operating as air tankers in a local refill mode.

F. Cost Module Output Format

The lack of season-by-season cost summaries where multi-year work loads are involved has been a big problem. Confusing terms such as "standby costs" and poor output layout have caused much misunderstanding. The new Cost Module format corrects these problems and harmonizes the technical terms with user manual methodology and definitions.

IV. FUTURE ROLE OF RESEARCH

A. Kind and Amount of FOCUS Support

1. Federal Research and Technology Transfer

The PSW Station will terminate FOCUS and FIRESCOPE on September 30, 1977 as planned. A new Research Work Unit composed of both staffs will begin on October 1, 1977 entitled Fire Management Planning and Economics. The Station's commitment to FOCUS implementation will continue within the new Project as part of the user assistance working team. The new Work Unit's budget for FY 78 for FOCUS technology

transfer will include the salaries of a Liaison Officer, a computer specialist and one computer technician (see Appendix B). PSW Experiment Station support would be budgeted for 2 years on a declining basis until October 1979, at which time full and complete maintenance of the system would be assumed by user groups. User ability to take over this function will be greatly enhanced by the detail of a W. O. computer specialist to the Fire Laboratory for a 6-month period starting early in FY 78. User assistance is continuing to be a big job--we continue to receive about 10 telephone calls per day asking for technical advice and consultation. This hasn't diminished over the past year and a half that the system has been undergoing operational testing. If the use of the system is expanded to include the proposed 50 National Forests, and particularly if it includes a number of additional states, we can expect the volume of technical assistance to increase over the next few years rather than wind down (see Appendix C). We believe that FOCUS is an exceedingly powerful fire management planning tool. It has been designed to cope with and handle almost every imaginable situation. However, its usefulness is very much dependent upon the skill and capability of the system managers. The W.O. is taking steps to establish a permanent well-trained and experienced group who are thoroughly familiar with the FOCUS computer system and fire control.

2. Schedule of FOCUS-Related Jobs to be Done

In addition to the basic research development and application jobs described, there are large numbers of important tasks that must be accomplished within the next 3 years. These include such jobs as development of Forest Service Manual directives, develop training courses and complete the technical documentation of the FOCUS system. These tasks are shown in Appendix D with personnel assignments and due dates.

B. Future Research Needs

1. Damage Module

The present FOCUS model requires considerable information about the fire location including fuel or vegetation type and some idea of value class. It also required information on fire rate of spread, weather, and time of year.

While the FOCUS output is in terms of acres burned by value class and utilization and cost of fire control resources, many of the ingredients are present to evaluate fire damage, provided we know about basic fire damage economic concepts. Some of the research conducted by the new Work Unit previously described will deal with fire damage relating it to land management planning with the eventual objective of developing a FOCUS damage module.

The original FOCUS concept was to develop a stochastic model (operating on the probability of fire occurrence, etc.) that would include suppression, detection, and prevention. In order to meet time schedules, the current FOCUS is a somewhat slimmed down version in which the stochastic capability was dropped and detection and prevention were not included. However, some work continued independently on both detection and prevention.

2. Detection Module

A detection module has been developed based on computer records of terrain data, that can be used to plot lookout seen areas and relate seen area patterns to fire intensity zones. Essentially, the system is an automated version of the procedure used to evaluate lookouts in the 1972 fire plan. The automation, however, enables the user to consider a wide variety of lookout locations, tower heights, etc., that would have been impossible to consider under the manual

evaluation system. Although not completed at this time, a logical future step should be the integration of aircraft flight lines into a total fixed-airborne detection system.

3. Prevention Module

A prevention module adaptable to FOCUS is being developed by the Fire Prevention Research Work Unit at both the Riverside Fire Laboratory and at Berkeley PSW Station. Much of the prevention model methodology is a direct spinoff from the effort to develop a man-caused fire generator for the stochastic version of FOCUS. Plans are now underway to integrate the prevention module into the total FOCUS system. We expect that within about a year FOCUS will be able to simulate both prevention as well as suppression and have the capability of evaluating tradeoffs between dollars invested in prevention versus suppression effort. A word of caution--while this will greatly increase the capability of the FOCUS system, it will also add a new dimension of complexity to the overall operation, emphasizing the need for a continuing management support group somewhere in the system which is both thoroughly familiar with fire control, computer technology, and the full and complete operation of the FOCUS system.

V. COORDINATION WITH OTHER SYSTEMS

A. Engineering

During the entire development phase of the FOCUS system, every effort was made to coordinate the definition of FOCUS data collecting requirements, with the needs of other land and fire management systems. This has been particularly true in relation to the Transportation Inventory System (TIS). Transportation is by far the single biggest data collection job in the FOCUS system. In developing the transportation network, it would have been highly advantageous if this job could have been shared with other forest management

functions. Consequently, we have worked very closely with the TIS system designers. Unfortunately, there was no general agreement on design requirements by that group in the time schedule necessary to meet FOCUS deadlines, so the FOCUS system was developed independently. However, there must be a continuing effort to integrate this phase of the FOCUS data collection as much as possible. The development of an integrated, coordinated transportation design system would save thousands of dollars on forests that both use FOCUS and are also collecting information for other transportation needs.

B. FIRESCOPE

On October 1, 1977 the members of FOCUS development team and FIRESCOPE teams will be combined in the new Fire Management Planning and Economics Work Unit. Already there are several beneficial spin-offs from this combination. These include an estimated time of arrival analysis system being developed by the FIRESCOPE group that uses the FOCUS transportation sytem and a real time, threat analysis procedure developed for dispatch action that uses the spreading elliptical fire pattern concept from FOCUS.

C. OTHER

A continuing effort will be made to monitor relevant research conducted in other locations around the country. Of particular interest is the work being done at Missoula on fire spread modeling and the role of fire in land management planning.

Appendix A

FOCUS Statistical Validation

Validation and verification are often confused. Verification is a checkout process to see that model does what the modeler planned for it to do. In a large model, this requires the subject mater expert to check his input, the programmer to check his code, and the analyst to check his algorithum in response to the model's output. This is more apt to be a continuing process with each new set of data than a one-for-all event. The terms "truth checking" or "fine tuning" are often substituted for verification with special emphases given to the data checking part. Any simulation model requires art as well as science on the part of the user to fit real world data into the model. A portion of the FOCUS users' manuals shows how to go through the various verification steps. Verification is not a critique of how well the model does or does not meet the variation of real-world inputs, but is the art of fitting a maximum amount of real world information into the complexity the model was designed to handle.

Validation is the checkout process that compares the model performance to the system being simulated. The answer is not one word like "valid" or "invalid" but rather "does the model work for the question or problem for which it is being used"--with a long list of qualifications. The user must ask a valid question before the model can give a valid answer. Asking the right question, predicting the right answer, costing the computer runs minimizing variance, and avoiding confounding is the science of experimental design, and are parts of the validation process.

Verification Status of Sequoia National Forest

George Flatman, of the FOCUS staff, conducted a statistical analysis of the Sequoia National Forest as partial work toward his Ph D. He found the Sequoia National Forest had a good source of historical

data in its fire reports. As simulation modeling situations go, there were more and better records availalbe than is often the case; yet, the information about some sensitive inputs was not as complete and accurate as we would have liked. The reports do not tell what the overall staffing of the suppression organization was during the 1960 decade--the period of FOCUS testing. There were large amounts of mutual aid where a substantial suppression contribution was made by the California Department of Forestry. These forces in the "sixties" had large honor-camp crews and their numbers of men and their availability to the Sequoia National Forest was not a matter of record. Three possible force levels were approximated and the two that appeared most realistic during truth checking were used during the validation simulation computer runs. Plan 1 was the organization representative of what actually existed during the 1960 decade and Plan 2 was the stronger organization based on the 1972 replanning by the Forest Service.

Validation Goal

A replication of fires from the two fourth (tied) worst years from 1960 decade was run through FOCUS. The road network, dispatch rules and fire control resource data sets were held constant for the 2 years. In the selection of years, the definition of "worstness" was based on numbers of ignitions and acres burned (Table 1).

The simulated (FOCUS) burned area and number of fires by size class were compared with historical (actual) burned and numbers of fires. The Forest Service size classes ($A = 0.25$ acre, $0.25 < B \leq 9.9$ acres, $9.9 < C \leq 99.9$ acres) were used in the grouping of data.

Essentially two types of questions were asked:

1. Does FOCUS adequately simulate (reproduce) the frequency of the fires within these classes?

Table 1. Selection of fourth worst fire year.

Year	No. of Fires		Acres Burned		Pooled
	No.	Rank	No.	Rank	Rank
1960	237	2	1170	7	4.5
1961	279	1	7777	2	1
1962	91	8	2002	4	6
1963	51	10	194	10	10
1964	80	9	1931	5	8
1965	181	4	243	9	7
1966	125	6	8398	1	2
1967	235	3	1273	6	4.5
1968	104	7	930	8	9
1969	165	5	2510	3	3

2. Do the residuals--the difference in size between actual and simulated fires--have a symmetric and normal shaped distribution? Is their mean zero and their variance finite and hopefully small?

In the discussion to follow "recorded" will refer to the historic burned area from fire reports, "plans 1 and 2" will refer to the simulated burned area form FOCUS outputs and δ will be the residuals (the difference formed by "recorded" minus "plans 1 or 2").

The computer simulation phases of FOCUS stops at a hundred acres because the modelers thought 100 acres to be the upper limit of elliptical fire spread model credibility. Fires greater than 100 acres (>C) are gamed by a team of local fire control experts. In practice, this is a reasonable breaking point, because a hundred-acre fire is big enough in time and area to be fought by crews called in from other forests, mutual aid groups, etc. This leads to some undesirable but unavoidable statistical problems.

The Chi-square Test was used to determine the "goodness of fit" of the actual data (from the fire reports) to the theoretical distribution (from FOCUS). The test involves the calculation of χ^2 (Chi-square).

$$\chi^2 = \Sigma\left[\frac{(f_o - f)^2}{f}\right]$$

where

f_o = the observed or actual frequencies

f = the theoretical frequencies

The Chi-square Test may be used to test a large variety of hypotheses by comparing the expected results (frequencies) based upon the hypothesis to be tested and the actual results obtained by sequencing observations. If the Chi-square test demonstrates that the disparity between the actual and the expected frequencies is too

large to be ascribable to chance (if p is less than the selected confidence level of 0.01 or 0.05), the hypothesis may be said to be false. In other words, if p equalled 0.10 there would be 10 chances out of 100 that the fit obtained would be as bad or worse than the one shown (10 chances out of 100 that the variations or departures from normality occurring in the sample might be either as bad or worse than those actually occurring), due to chance fluctuations with no real departure from normality.

Table 2 makes three goodness of fit comparisons:

1 - recorded 1960 fires to simulated plan 1 for 1960 fires
2 - recorded 1967 fires to simulated plan 1 for 1967 fires
3 - recorded 1960 fires to recorded 1967 fires

The first line of each comparison is used as the expected (from the fire report) value in computing Chi-square. In the third comparison 1967 is scaled to match totals with 1960. All three are acceptable fits but the important fact is to rank the comparisons.

Both simulated Plans 1 and 2 and recorded within 1960 and 1967 have smaller Chi-squares and thus a better fit than the two recorded two fourth worst years. The third comparison gives an example of an acceptable level of difference. Either one of these years could have been used for planning purposes. They were tied for fourth worst year. Yet their difference is larger than the difference between a FOCUS simulated year and its recorded antitype.

Pairwise examination of area burned

Area burned on a fire-by-fire basis is not the important factor in planning. The number of escapes, as tested in the size class comparisons, is a better indicator of damage and fire plan acceptability. To compute a correlation between the recorded fire and its simulated counterpart, the escapes in each group must be excluded.

Table 2. Frequency of fires by size class over years.

Source	A	B	C	>C	Sum of Chi-square
Within 1960					
Reported	205	25	2	2	expected
Plan 1	211	18	3	2	observed
Contribution					
to Chi-square	.1756	1.96	.5	0	2.64 ns[1]
Plan 2	215	17	1	1	
Contribution					
to Chi-square	.4878	2.56	.5	.5	4.05 ns[1]
Within 1967					
Reported	214	15	2	2	expected
Plan 1	211	17	3	2	
Contribution					
to Chi-square	.042	.267	.5	0	.81 ns[1]
Plan 2	215	12	4	2	
Contribution					
to Chi-square	.005	.75	2	0	2.76 ns[1]
Between years					
Reported 60	205	25	2	2	expected
Reported 67	215	15	2	2	
Contribution					
to Chi-Square	.488	4.00	0	0	4.488 ns[1]

[1]ns = not significant

In Plan 1, there are four escapes as in the recorded fires but these were not all pairs. Only two of the escapes were the same fires as recorded and thus six fires have to be dropped, and four fires were not simulated so n is 461 for the combined years. The correlation coefficient for Plan 1 burned area against the recorded data is .358 and

$$P_F(.28 \leq \rho \leq .44) = .95$$

The correlation coefficient can be severely changed by just a few outliers (values beyond a given number of standard deviations from the mean) in even a large sample. In a sample size of 461, one would expect 1.2 outliers beyond six sigma. Rejecting fires 70 and 191 from year 1967, the correlation coefficient becomes .607 and

$$P_F(.56 \leq \rho \leq .67) = .95$$

The square of the correlation coefficient is known as the index of determination. In our example, the value of .61 squared or 37.2 percent indicates that the simulated area explains 37.2 percent of the variation in recorded area burned. For the same reasons except one less escape, Plan 2 has an n of 462. The correlation coefficient between the recorded areas and the simulated is .619 and

$$P_F(.57 \leq \rho \leq .67) = .95$$

Table 3 shows that the residuals of Plans 1 and 2 are not normal. The Chi-square goodness fit is too high, indicating too large a difference between the expected frequencies for the normal and the observed counts of residuals. The test statistic is significant at the 99.5 percent level (indicated by quadruple asterisks).

The means of Plans 1 and 2 in both abridged and unabridged versions are in Table 4. A fiducial interval about the mean shows the probability that the random interval $\bar{\delta} \pm ts$ will contain the fixed μ, is 0.095. The critical values are from an extension of E. S. Pearson's table by N. L. Johnson and others (1963) that gives the critical values as a function of skewness and kurtosis and

Table 3. Goodness of fit by abridged residuals from Plans 1 and 2.

	-1 1/2s	-s	-1/2s	$\bar{\delta}$	+1/2s	+s	+1 1/2s
Plan 1							
Expected	4.21	5.78	9.27	12.06	12.06	9.27	5.78	4.21
Observed	2	3	4	25	23	3	0	3
Contribution to χ^2	1.160	1.337	2.996	13.884	9.924	4.240	5.780	.348
Plan 2							
Expected	4.00	5.51	8.83	11.49	11.49	8.83	5.51	4.00
Observed	3	1	1	19	31	1	2	2
Contribution to χ^2	0.250	3.691	6.934	4.909	33.128	6.943	2.236	1.000

Sum of Chi-square

Plan 1 = 39.669****

Plan 2 = 59.1****

Table 4. Parameters of the samples.

	All Residuals	Nonzero Less Two Outliers
Plan 1		
	$n = 461$	$n = 63$
	$\bar{\delta} = -.2957$	$\bar{\delta} = .0302$
	$s = 5.0988$	$s = 4.5591$
	var $(\delta) = 25.9975$	var $(\delta) = 20.7850$
	skewness = -9.09	skewness = 1.55
	kurtosis = 185.50	kurtosis = 13.41
Plan 2		
	$n = 462$	$n = 60$
	$\bar{\delta} = .1359$	$\bar{\delta} = .0233$
	$s = 3.6608$	$s = 6.3998$
	var $(\delta) = 13.4012$	var $(\delta) = 40.9571$
	skewness = -.95	skewness = -1.25
	kurtosis = 98.11	kurtosis = 10.82

Plan 1 $P_F(6.79 \leq \mu \leq 10.88) = .95$

Plan 2 $P_F(15.27 \leq \mu \leq 9.5314) = .95$

Since zero is in all these intervals, the means are not different from zero at the 95 percent level. The means of the samples of residuals being not different from zero indicates there is no additive bias.

The coefficient of skewness (the lack of symmetry in distribution) should approach zero for the normal and the coefficient of kurtosis (the degree of peakedness of a distribution) should approach three. Both of these indicators are too far removed to warrant testing. The nonzero residuals are still peaked but now skew to the right or positive values for Plan 1, but skew to the left or negative values for Plan 2. The change in sign in the means and indices of skewness suggests that Plan 1 is weaker than the actual historical suppression forces and Plan 2 is stronger than the historical force. This is as would be expected since Plan 2 is the stronger organization, based on the 1972 Forest Service replanning.

The standard deviations are shown in Table 4. The variances should be finite and hopefully small. The hypothetical range of the residuals would be from 0 minus 100 (100) to 100 minus 0 (+100). A rule of thumb suggests that the variance is a sixth of the range for very large samples. This would give an estimate of 33. Compared to this value, the standard deviations are small. The variance of the residuals is consistent with the variances and correlation of the actual and simulated burned area.

$$\sigma^2(\text{residuals}) = \sigma^2(\text{recorded}) + \sigma^2(\text{plan i}) - 2\,\rho\,\sigma(\text{recorded})\sigma(\text{plan i})$$

Plan 1

$$(5.0988)^2 \equiv (1.9399)^2 + (5.4601)^2 - 2 \cdot .385 \cdot 1.9399 \cdot 5.4601$$
$$25.9978 \equiv 25.9920$$

Plan 2

$$(3.6608)^2 \equiv (2.2379)^2 + (4.5974)^2 - 2.619 \cdot 2.2379 \cdot 4.5974$$
$$13.4012 \equiv 13.4071$$

Table 5 shows the correlation coefficients for the residuals and their parent populations, i.e., the recorded and simulated burned areas. Only Plan 2 in the unabridged group has a correlation with the recorded areas that is significantly different from zero.

It is desirable that the residuals are not correlated with the parent populations. All correlations between residuals and the parent simulated sample are different from zero. However, the high correlation coefficients are very dependent on a few outliers. The correlation drops to less than half its former value when Plan 1 removes only two forests from the unabridged to form the abridged sample.

Another important test for the residuals of a large computer simulation is the sign test or run test. This test looks at the residuals over time. In FOCUS, the fire number places all fires in chronological sequences. If the residuals are of the same sign for long periods of time, the model has the bias of time dependency. For example, if the model did not take fire danger into account in the dispatch data set and the manning levels in the resource data set, the residuals would be positive because of simulation overkill in the early and late fire season, but negative in midseason due to inadequate attack. This situation would be picked up by the sign or run test as too few runs or changes in sign. In applying the sign test, the 401

Table 5. Correlation of residuals with recorded and simulated parent samples.

Residuals	Recorded	Simulated
Unabridged		
Plan 1	-.003 ns[1]	-.935
Plan 2	-.166	-.877
Abridged		
Plan 1	.051 ns[1]	-.418
Plan 2	-.142 ns[1]	-.377

[1]ns = not significant; others significant.

zero values were ignored. The number of runs has a normal distribution. The rejection region is the ususal normal two tail test. The negative tail indicates too few runs, and the positive tail too many runs.

Some authorities are concerned only about too few runs and suggest there cannot be too many. However, too many runs may suggest some hypersensitivity in the model and an instability in the solution.

Solution to run test:

Let n_1 = No. of + residuals

n_2 = No. of residuals

u = No. of runs

$$u \; N\left(\frac{2n_1n_2}{n_1 + n_2} + 1, \; \frac{2n_1n_2(2n_1n_2 - n_1 - n_2)}{(n_1 + n_2)^2(n_1 + n_2 - 1)} \right)$$

Observed	Plan 1	Plan 2
n_1 =	32	29
n_2 =	23	31
u =	31	32
Computed		
$\bar{u}_1$ =	28	31
s^2 =	12.77	14.71
Test Statistic	0.84	0.26
Rejection Region	<-1.96 and >1.96	

Since 0.84 and 0.26 are not in the rejection region, the residuals of both plans have an expected number of runs or sign changes which indicate the absence of time dependence.

Summary

The correlation of simulated and recorded burned areas was acceptable but not outstanding. However, this test is not well suited to the correspondence sought here because it omits escapes and is a pairwise comparison. The pairwise agreement is not necessary for planning purposes and emphasizes discrepancy between pairs of fires. This discrepancy may be due to simulation error, recording error, random variation, or some mixture of these three. The first two sources of discrepancy are unwanted, but only the first can be corrected by the model builder. The third source is very desirable and an essential input to realistic planning.

The frequency by size class analysis using the Chi-square goodness of fit test found an acceptable correspondence between simulated and recorded fire size. This test was able to show that the agreement of recorded versus simulated was better (lower sum of Chi-square) than the agreement between the two historical examples of a planning year.

Lastly, the analysis of residuals showed the errors to have a mounded and reasonably symmetric distribution. The mean of the residuals was not different from zero and their variance is finite and small. There is no bias or time dependency detected by the mean or the sign test. The residuals are correlated with the simulated area burned, but otherwise appear to be random. Whether these residuals are in fact simulation errors or recording errors will not detract from their use to make a historical year into a more general planning base since they appear random, and have a mounded and symmetric distribution with mean zero and finite variance.

Based upon all statistical validation tests to date, there is no reason to question FOCUS' ability to model the nonescape fire event.

Appendix B

The enclosed table and chart is a suggested budget for user financial support for the FOCUS effort in FY 78. FY 79 is also indicated to show trends in changing workload support arrangements. This has been partially generated by the need to plan the new project which will start next October 1. So, this thinking and the figures involved are also part of that effort because FOCUS implementation and user assistance is a part of this new Work Unit, referred to as 2111.

Assumptions behind this format and dollar amounts are:

1. Station has pledged a minimum level of liaison and technical support assistance (about 2 man-years equivalent).

2. NFS will probably accept FOCUS as a "national system" about October 1.

3. NFS (fire) computer support group will not be able to technically help the user for about 1 year upon entry into the technical transition phase. In the event that they would recruit a qualified FOCUS systems person on their staff, the 1 year time delay could be cut to about 3 months.

4. User assistance load in FY 78 will be about 50 percent higher than this fiscal year (17 new National Forests, 5 states, and 3 other agency units plus support energies still required for existing planning units working with FOCUS).

5. Documentation system (seven components) will be completed about October 1.

Consequences of lack of indicated support:

1. A reduction of across-the-board services and negative impact on other liaison aspects of Project 2111.

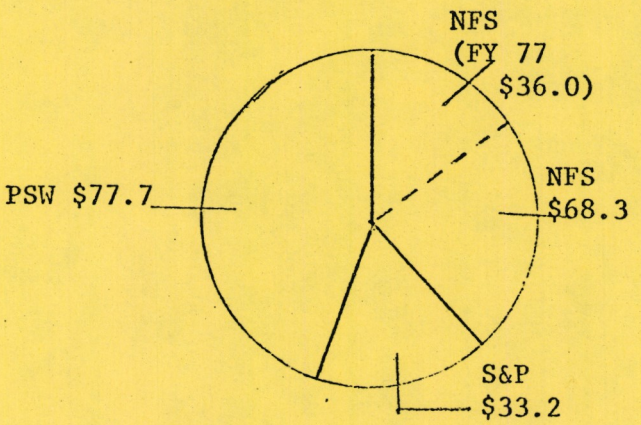
2. A failure to meet the Chief's Fire Management 1980 goals. Attachment 2 of the "FOCUS Pilot Test Evaluation and Implementation Plan Review" (Appendix C) assumes a minimum $25,000/unit/year Regional and WO support. A recent survey of the regions indicates that the field (on the average) will meet only 50 percent of the financing level, yet production expectations are unaffected. Such actions will simply shift the technical support role to WO.

FOCUS REMNANT
USER ASSISTANCE COSTS
(Anticipated) FY 78-79 as part of Project 2111

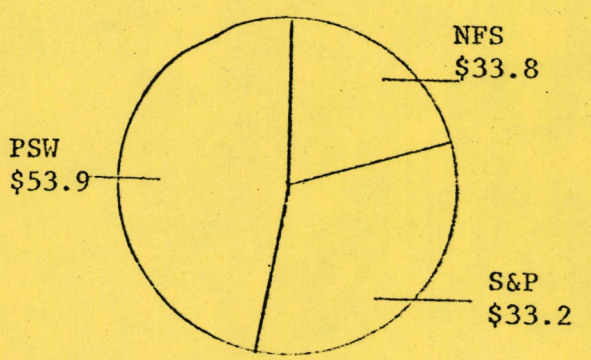
Budget Items		Dollar Needs ($1,000) 1978		1979	Suggested Support Sponsor
Salaries					
Keith, Computer Programmer (50%) and 1 S&P Comp. Techn.	8.8 14.5	23.3		23.3	S&P
Keith Computer Programmer (50%) and 1 NFS Comp. Techn.	8.8 14.5	23.3		8.8*	NFS
Rapp, Liaison	(90%)	45.0	(50%)	25.0	NFS
Phoenix, Liaison (Consultant)		4.5		4.5	S&P
Project Leader	(20%)	11.0	(10%)	5.5	PSW
Bratten	(30%)	15.0	(15%)	7.5	PSW
		122.1		74.6	
*Computer technician provided by NFS Systems Group.					
Travel					
Phoenix, Liaison		5.4		5.4	S&P
Rapp, Liaison		10.8		10.8	S&P
Computer Technicians		9.1		9.1	PSW
		25.3		25.3	
Support					
Computer Costs		21.2		16.0	PSW
Supplies, Publications, etc.		10.6		5.0	PSW
		31.8		21.0	
		179.2		120.9	

SUPPORT BREAKDOWN

1978 ($1,000)



1979 ($1,000)



Appendix C

SUMMARY OF FOCUS COST AND MANPOWER ESTIMATE

It is Fire Management's goal to have 50 National Forests using FOCUS by 1980. This represents an average implementation schecule of 17 National Forests a year ago. The report indicates that on the pilot test units, the cost to implement FOCUS ranged from $15,000 to $25,000 per unit including salary, travel, computer operation, and analysis time. Other cost estimates are:

$2,200/unit/year for the maintenance of the unit's data files

$200/unit/year to update the information in the data files

$25,000/unit/year for Regional and WO support (assume at least one person per Region and one person in the WO; although some Regions may require two support people; assumes a salary for GS-12/1 is $23,000 plus $2,000 for travel)

$1,000/unit/year for training (this assumes we train one person per unit for 2 week's salary $900, computer time $100

$1,500/year for the central maintenance of software

We have no estimate for the cost of updating the documentation or for the preparation of training material. Updating the documentation can be assumed to be a periodic cost to be incurred, while the preparation of training material will probably be a one-time cost. In order to complete user documentation currently under contract by the PSW-Riverside Fire Laboratory, Research will have spent approximately $28,000; NFS and S&PF contributed significantly to this endeavor.

SUMMARY OF TOTAL FOCUS IMPLEMENTATION COST ESTIMATES

	LOW	HIGH
Implementation costs: 17 Forests/year	$255,000/year	$425,000/year
Low: $15,000/Forest		
High: $25,000/Forest		
Maintenance of local files	$ 37,400/year	$ 37,400/year
$2,200/Forest, 17 Forests/year		
Regional & WO Support	$250,000/year	$250,000/year
$25,000/Unit, 10 Units/year		
Training: $1,000/Forest, 17 Forests/year	$ 17,000/year	$ 17,000/year
Maintenance of software: $1,500/year	$ 1,500/year	$ 1,500/year
TOTAL COSTS	$564,300/year	$734,300/year
TOTAL COSTS FOR IMPLEMENTING FOCUS		
ON 50 FORESTS BY 1980	$1,815,300	$2,325,300

SUMMARY OF FOCUS MANPOWER ESTIMATES

Average man-months/planning unit	16.3 man-months/unit
Regional and WO Support	12.0 man-months/unit

Annually

16.3 man-months/unit (17 units)	277.1 man-months/year
Regional & WO Support	
12 man-months/unit (10 units)	120.0 man-months/year
TOTAL	397.1 man-months/year
	or
	33 man-years/year

Total man-months of work for implementing FOCUS on 50 units by 1980 = 1191.3 man-months or 99.3 man-years.

Appendix D

FOCUS Tasks to be Done

The following charts list a series of action items, assignments and target dates needed to complete all phases of the FOCUS technology transfer by October 1, 1980. Two important items in the scheduling are:

1. Complete the necessary steps to have FOCUS accepted as National program by October 1, 1977 or as soon as possible thereafter.

2. Make a complete and orderly transfer of all FOCUS activities from Research to the National Forest System by no later than October 1, 1980. The transfer process envisions a gradual phaseout of Research involvement and assumption of responsibility by the users.

ACTION ITEM	AS[illegible]ED	Begin	End
1. Provide criteria for Unit implementation (All levels) Involve Regions in this effort. Provide organizational alternatives at all levels. TCN	Mann	7/5/77	9/1/77
2. Prepare FSM Directive on:	Mann	7/1/77	9/1/77
a. Rate of spread	Davis - standard criteria		
b. Production rates	Mann		
c. Unit comparison	Davis		
d. Fourth worst year	Mann		
e. Basic assumptions	Davis		
f. Base plan validation	Mann		
g. Record keeping standards	Mann		
h. Fire planning criteria, policy & standards (How FOCUS fits into Fire Planning process)	Mann/Davis		
i. Truth check base plan	Davis - Procedures spelled out in User Manual		
3. Define F.S. FOCUS responsibilities with/to other agencies	Mann	10/1/77	11/1/77
4. Initiate FM Review & Accomp. Process	Mann	11/1/77	2/1/78
5. Assign implementation responsibility of A&FM System Support Group regard to FOCUS Organizational needs & tech. transfer from research to Systems Support			
6. Develop draft letter to Regions & Research & S&PF regarding FOCUS implementation - for TCN Direction to RF	Mann	6/30/77	7/1/77

ACTION ITEM	ASSIGNED TO	TARGET DATE	
		Begin	End
7. Develop summary report (action plan) for TCN on FOCUS issues & answers & request implementation approval	Mann	9/1/77	9/15/77
8. Convene task force to deal with:			
a. Rates of spread problem	FFASR	8/15/77	open
b. Production rate	FFASR	8/15/77	open
c. Historical fire data	Fenstermaker	9/1/77	10/1/77
d. Future fire data	Harden, Price, Mann	7/1/77	3/31/79
9. Define roles & responsibilities of A&FM System Support Group regard to FOCUS. User assist. & mtce.	Fenstermaker	7/1/77	9/1/77
10. Maintain (approved) computer support programs for FOCUS use (presently there are 12).	Fenstermaker	7/1/77	contin.
11. Develop a plan to disseminate FOCUS support program information to users & maintain source through:	Fenstermaker, Mann	7/1/77	8/1/77
a. Documentation control system, i.e.,			
1. Directives			
2. FCCC - terminals			
3. Telephone requests			
4. Write-ins			

ACTION ITEM	ASSIGNED TO	TARGET DATE	
		Begin	End
b. Training & seminars, workshops			
c. Continuing form for info exchange			
1. NWCG - Fire Planning Team			
2. NFS - Fire Planning Task Force selected			
12. Facilitate development of selected new computer support programs	Fenstermaker	Continuing	
13. Monitor transportation planning data/ information effort - provide POCUS needs input where applicable & recommend FOCUS modifications where feasible	Fenstermaker	7/1/77	open
14. Explore overlap with ADVENT	Fenstermaker	7/1/77	4/1/78
15. Develop objective oriented criteria for: selection, training, and promotion of personnel required to manage the FOCUS suppression module.	Mann/Davis/Fenstermaker	10/1/77	4/1/78
16. Existing documentation distribution plan	Mann	6/30/77	7/1/77
17. Respond to R-5 request	Mann	6/20/77	9/8/77
18. Develop interagency FOCUS workshop for the winter 1977/1978	Mann	6/30/77	11/1/77
19. Develop interagency FOCUS test course for the winter FY 1979.	Mann	7/1/77	10/1/77

ACTION ITEM	ASSIGNED TO	TARGET DATE	
		Begin	End
20. Develop interagency FOCUS for the standard course winter FY 1980.	Mann	7/1/79	10/1/79
21. Develop FOCUS training course FY 1981	Mann	7/1/80	10/1/80
22. Develop simulation and truth checking models for input into FOCUS training courses/workshops	Fenstermaker	6/30/77	11/1/77
23. Develop computer related training packet for input into FOCUS training courses/ workshops, i.e.,	Fenstermaker		
a. Terminal use	Existing FCC course for computer specialist & should be prerequisite for FOCUS training for computer specialist		
b. FCCC - operating system introduction			
c. File handling procedures			
24. Develop field data collection process for input into FOCUS training courses/ workshops	Rapp	7/1/77	9/1/77
25. A&FM make recommendation regarding Research's validation/certification effort plus assumptions & limitations	Mann	6/30/77	8/1/77
26. Complete technical documentation of computer programs.	Fred Bratten	1/1/77	12/31/77

ACTION ITEM	ASSIGNED TO	TARGET DATE	
		Begin	End
27. Complete assigned program modification, i.e., head attack, etc.	Fred Bratten	1/1/77	10/1/77
28. Clarify & agree upon future role of Research with respect to FOCUS	Davis	6/30/77	9/1/77
29. Improve data handling procedure for NFS	Fenstermaker	10/1/77	open
30. Develop implementation activity flow chart	Fenstermaker	7/1/77	8/1/77
31. Memo from Chief officially dissolving steering committee	Mann	9/1/77	10/1/77
32. Research identify the sensitivity of the FOCUS model to particular data items	Davis	7/1/77	9/1/77

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23. Develop computer related training packet for input into FOCUS training courses/ workshops, i.e.,	Fenstermaker		
a. Terminal use b. FCCC - operating system introduction c. File handling procedures	Existing FCC course for computer specialist & should be prerequisite for FOCUS training for computer specialist		
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